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Mathieu et al.

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(54) **ROBOTIC CLEANER**

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A47L 9/04 (2006.01)
A47L 9/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A47L 9/0477*** (2013.01); ***A47L 9/009*** (2013.01); ***A47L 9/0494*** (2013.01); *A47L 2201/04* (2013.01)

(58) **Field of Classification Search**
CPC A47L 9/0494; A47L 2201/04; A47L 9/28; A47L 9/2805; A47L 9/2836; A47L 9/2889
USPC 15/383
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,760,390 A 6/1998 Vezzalini et al.
8,452,450 B2 5/2013 Dooley et al.
9,211,045 B2 * 12/2015 Li A47L 11/4058
2004/0204792 A1 * 10/2004 Taylor G05D 1/0274 700/245
2007/0100500 A1 * 5/2007 Abramson A47L 9/0483 701/2
2015/0208891 A1 7/2015 Jang et al.
2016/0015233 A1 * 1/2016 Uphoff A47L 9/0455 134/6
2016/0320777 A1 11/2016 Yun
2017/0001311 A1 * 1/2017 Bushman A47L 9/2826
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2019201754 A 11/2019
KR 20030013008 A 2/2003

OTHER PUBLICATIONS

PCT Search Report and Written Opinion dated Feb. 26, 2021, received in corresponding PCT Application No. PCT/US20/63981, 10 pages.

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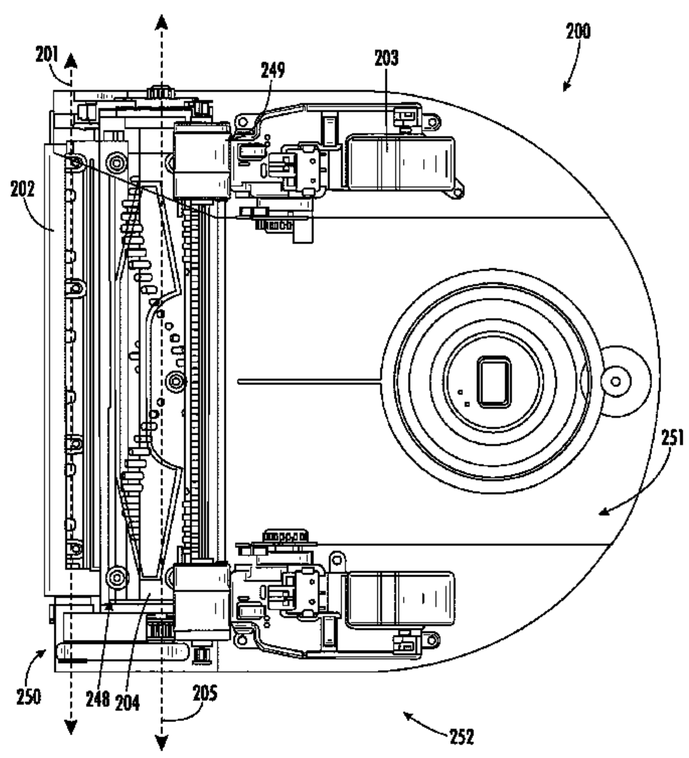
(57) **ABSTRACT**

A robotic cleaner may include a housing, an agitator, and one or more projections. The housing may have a front side, a back side opposite the front side, a left side, and a right side opposite the left side. The right and left sides extend between the front and back sides. The agitator may be configured to rotate about an agitator rotation axis, the agitator rotation axis extending substantially parallel to the front side. The one or more projections may extend from the housing. The one or more projections may include one or more cliff sensors.

4 Claims, 14 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2018/0169863	A1	6/2018	Bushman et al.	
2018/0338656	A1	11/2018	Carter et al.	
2018/0360281	A1*	12/2018	Shin	A47L 9/04
2019/0038107	A1*	2/2019	Jang	A47L 11/4044
2019/0090705	A1	3/2019	Thorne et al.	
2020/0367715	A1	11/2020	Doughty et al.	

* cited by examiner

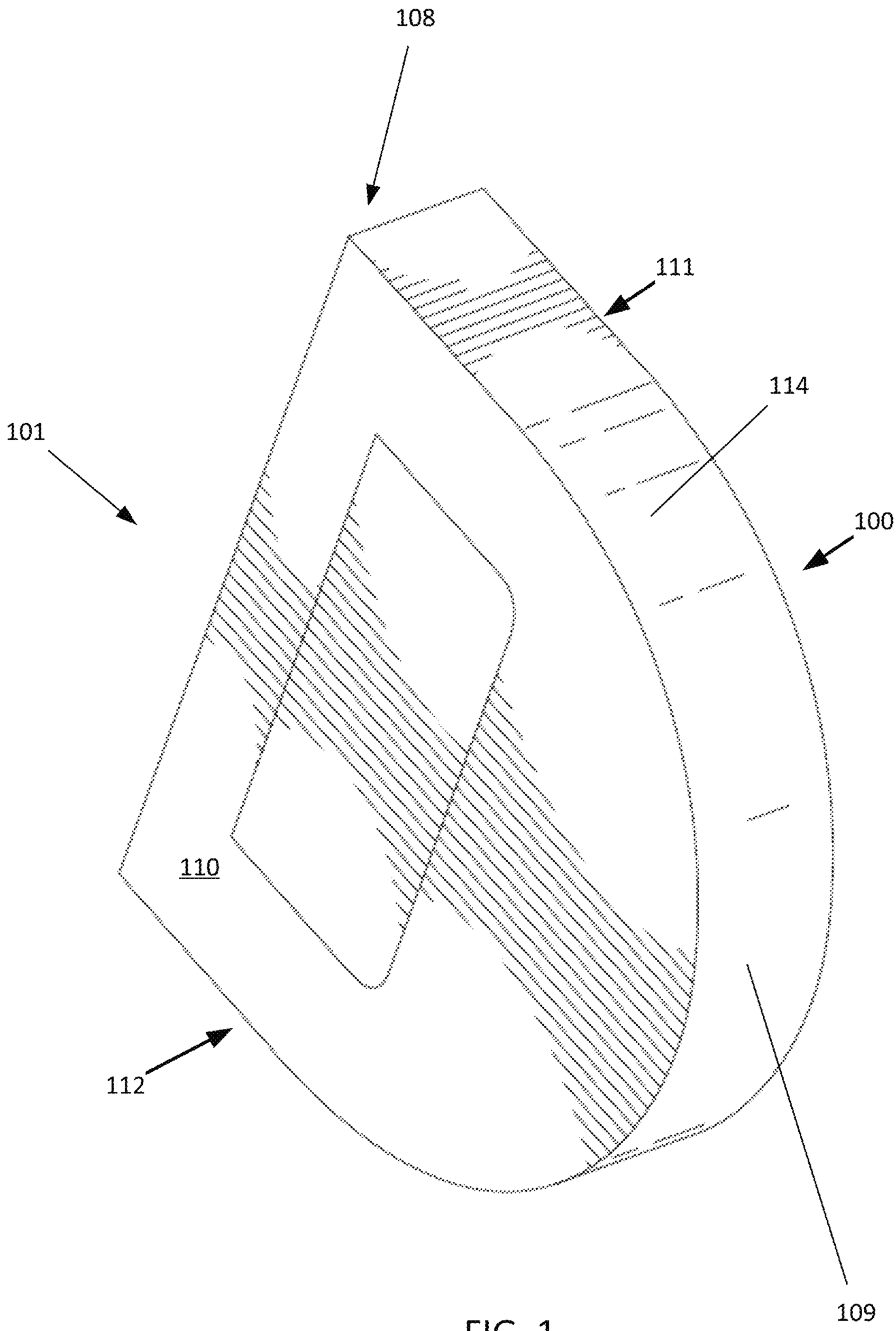


FIG. 1

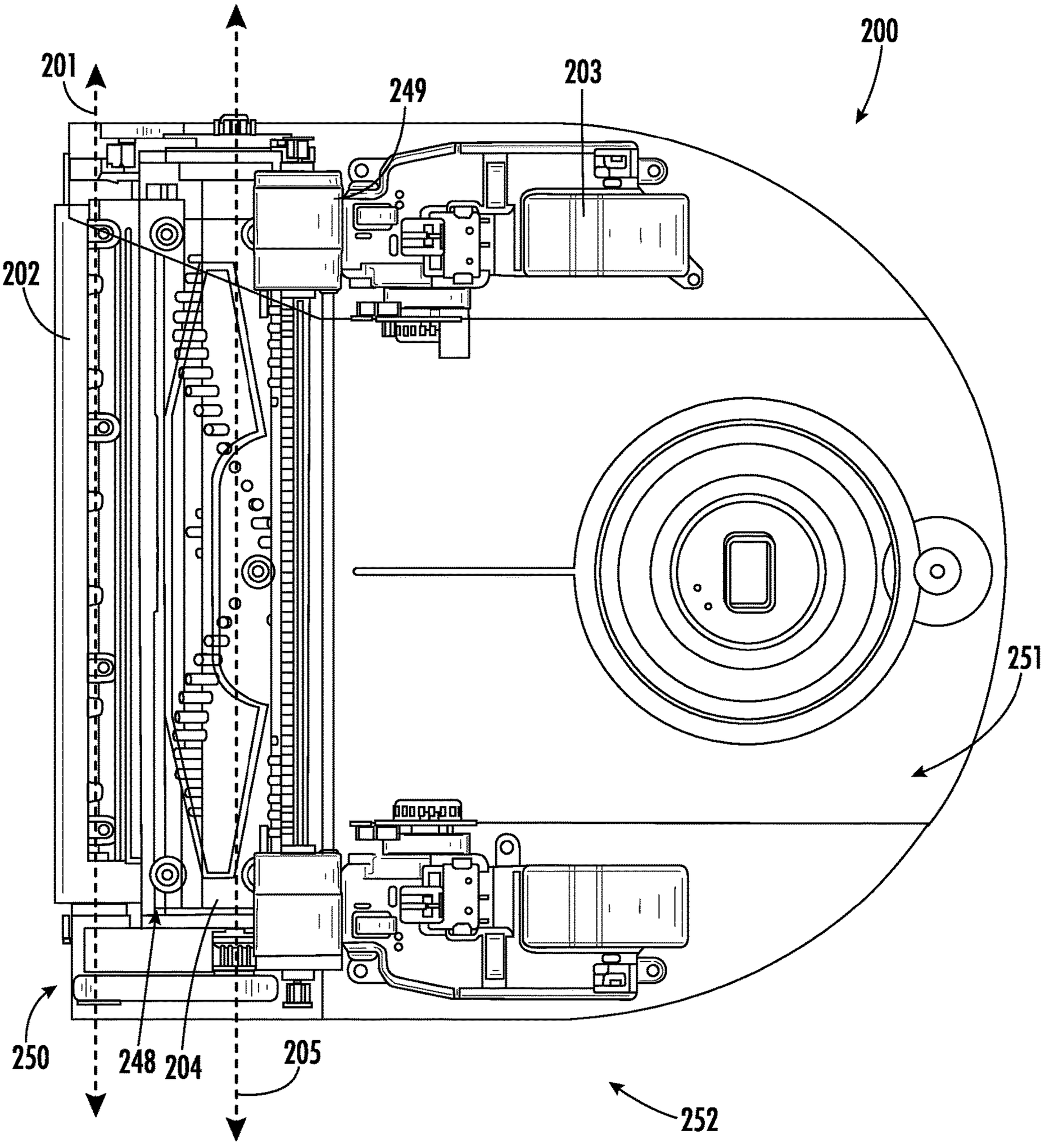


FIG. 2

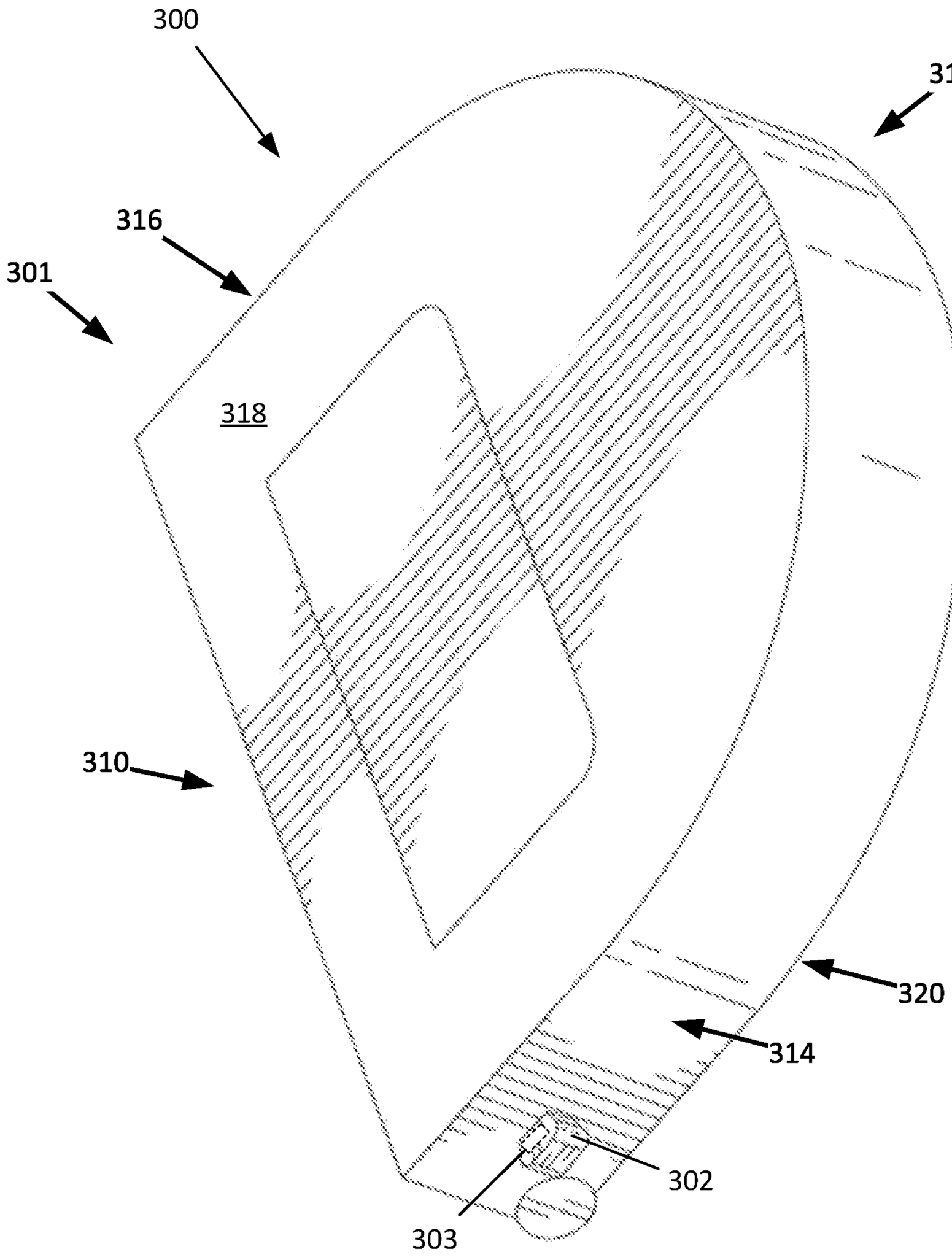


FIG. 3

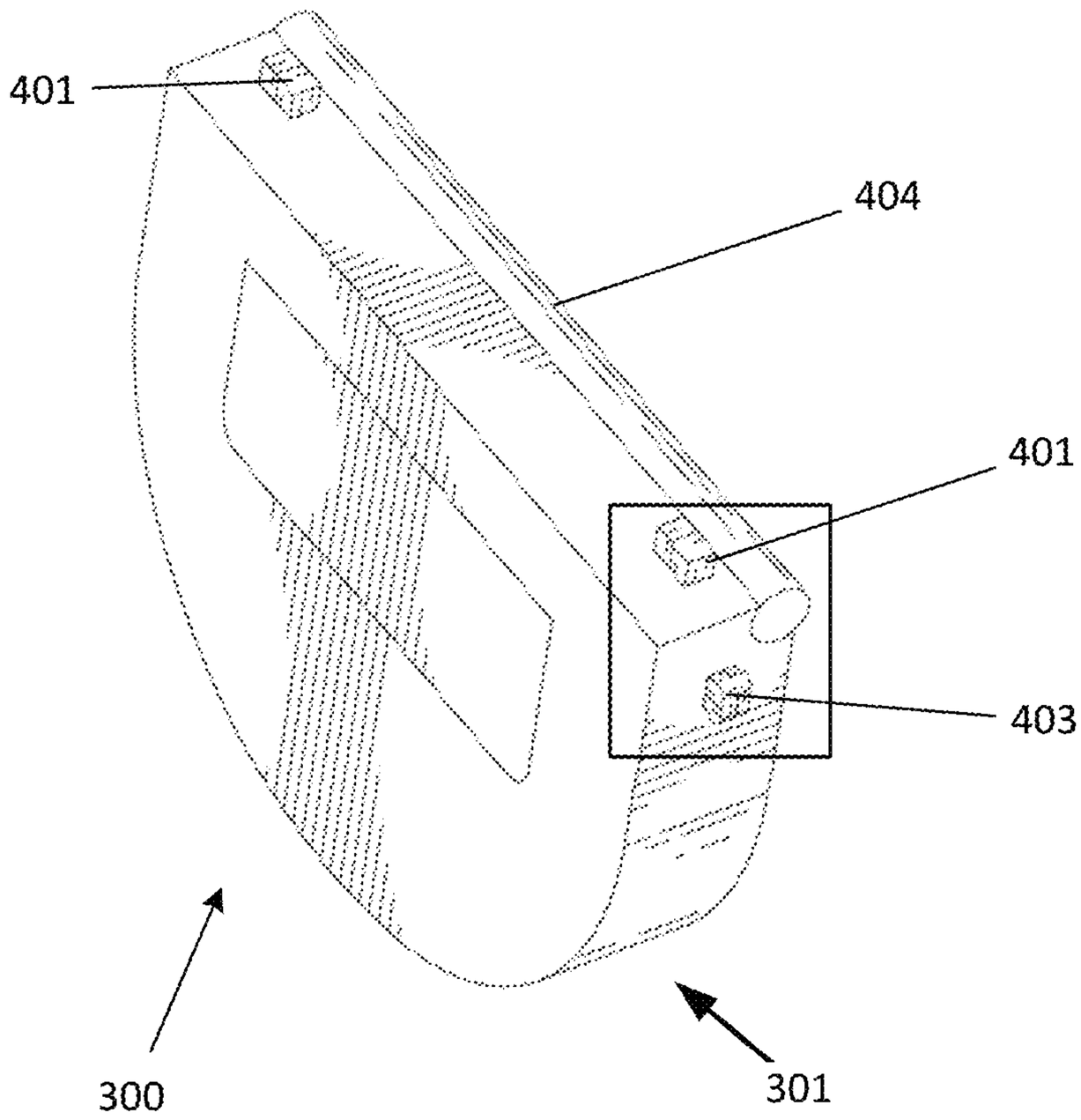


FIG. 4A

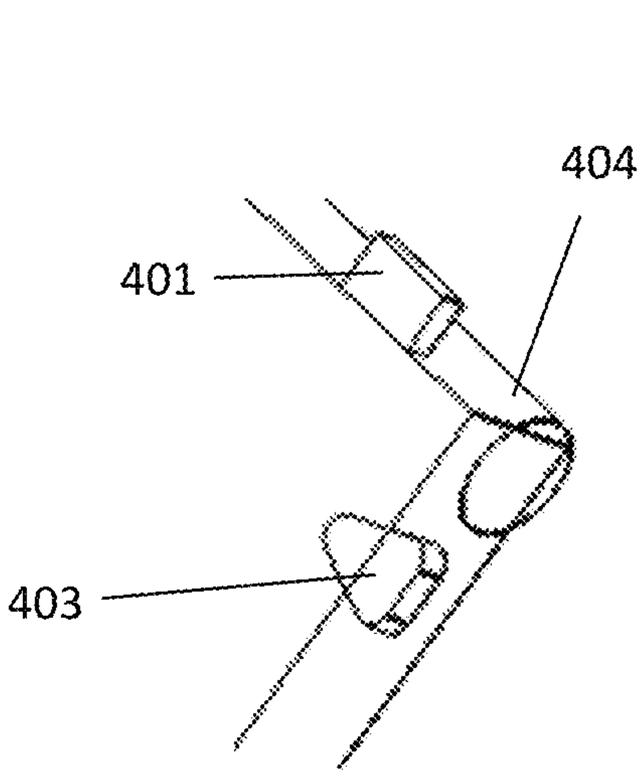


FIG. 4B

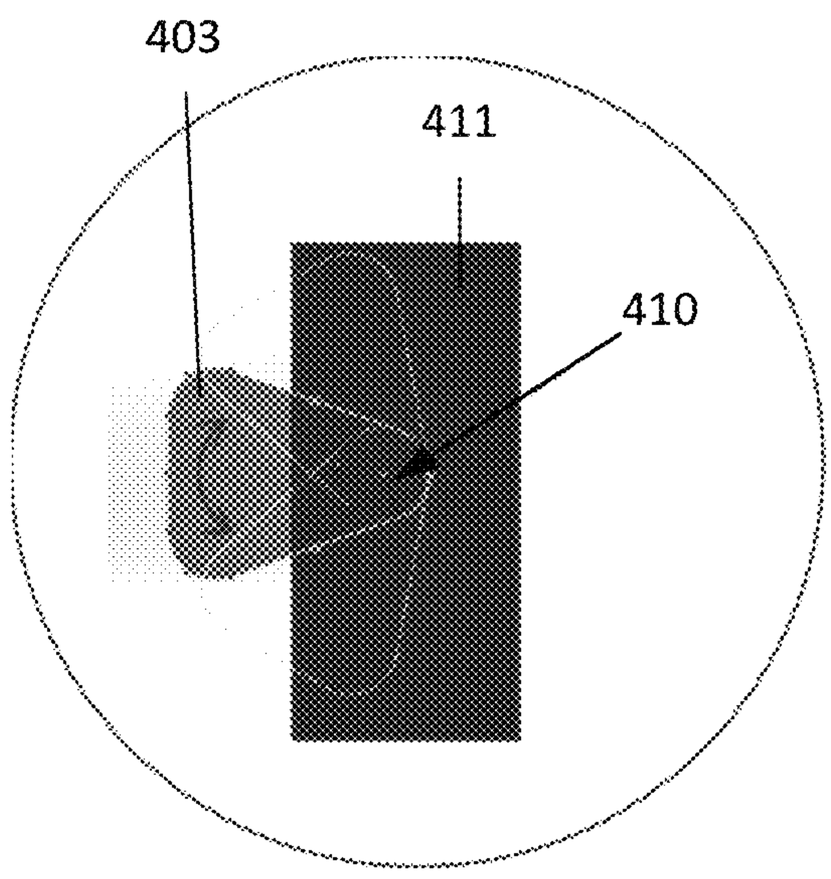


FIG. 4C

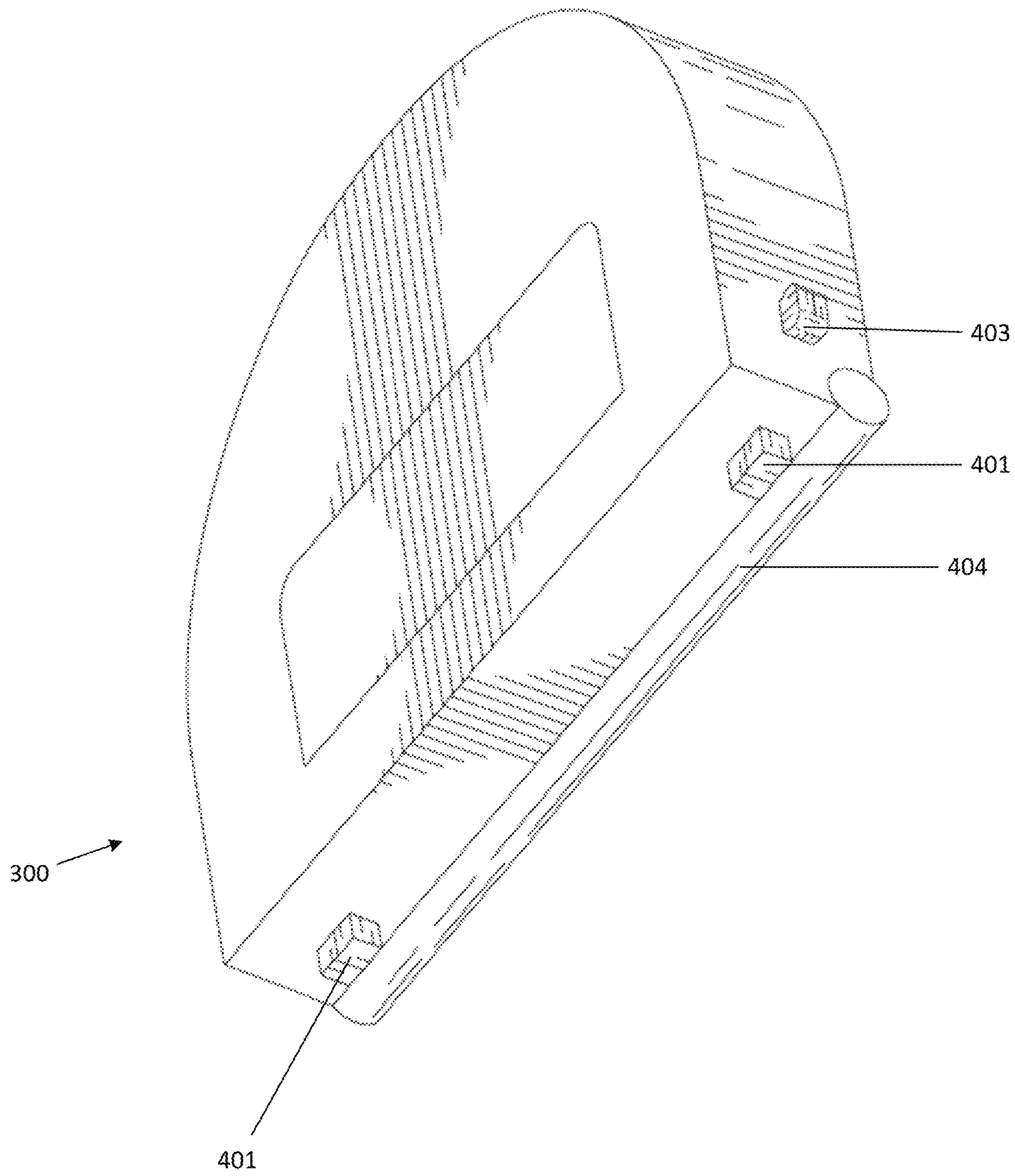


FIG. 5

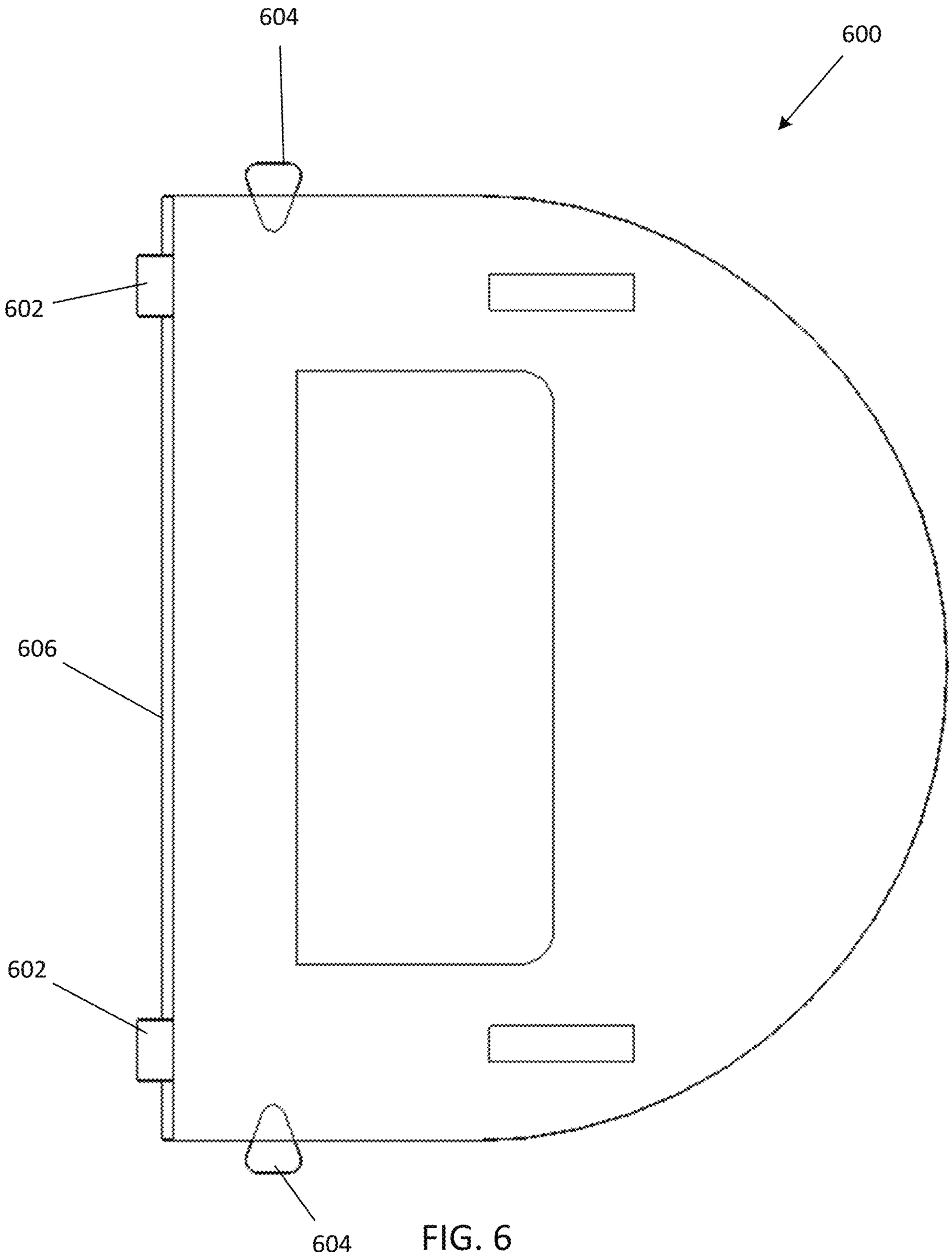


FIG. 6

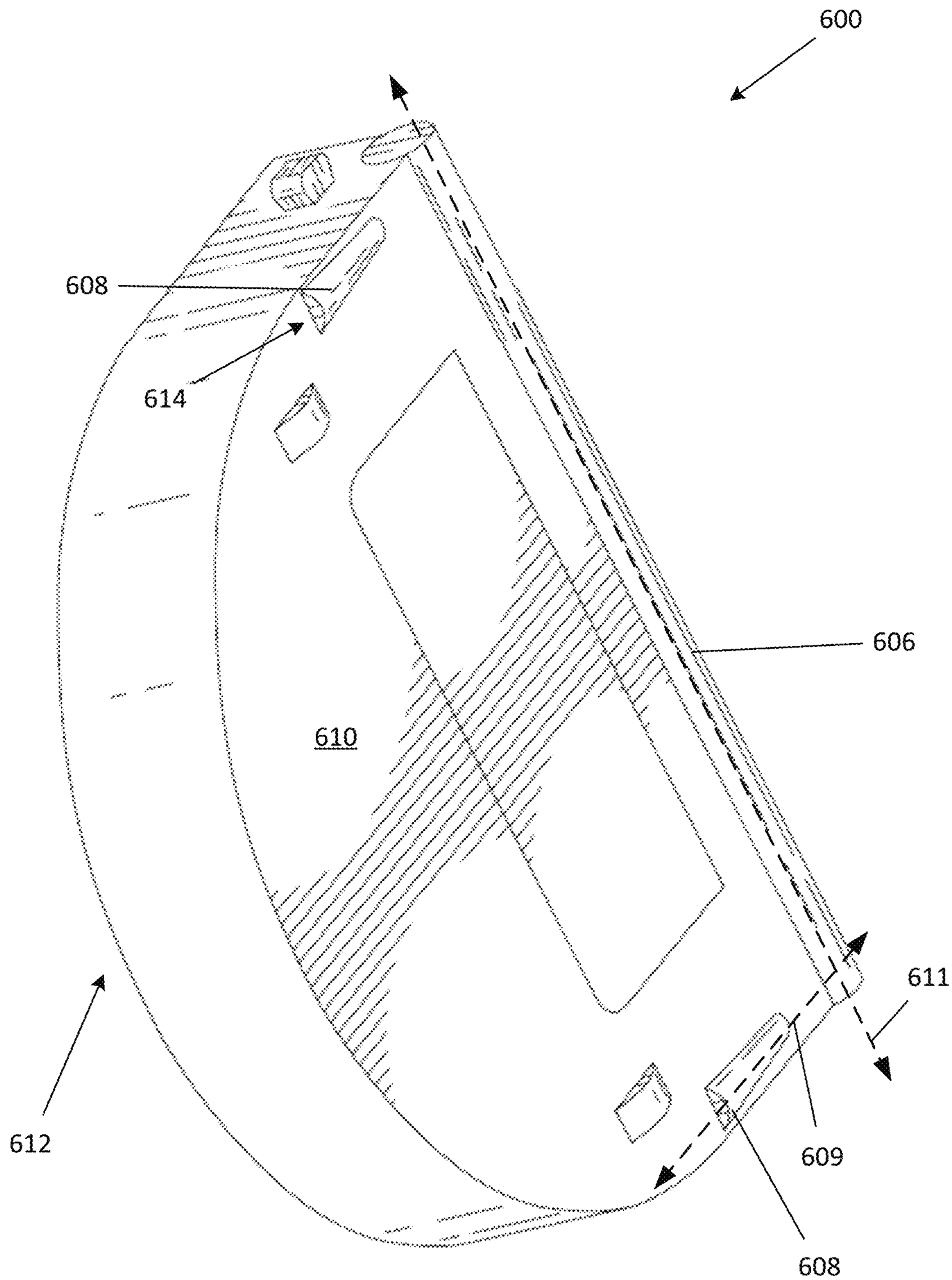


FIG. 7

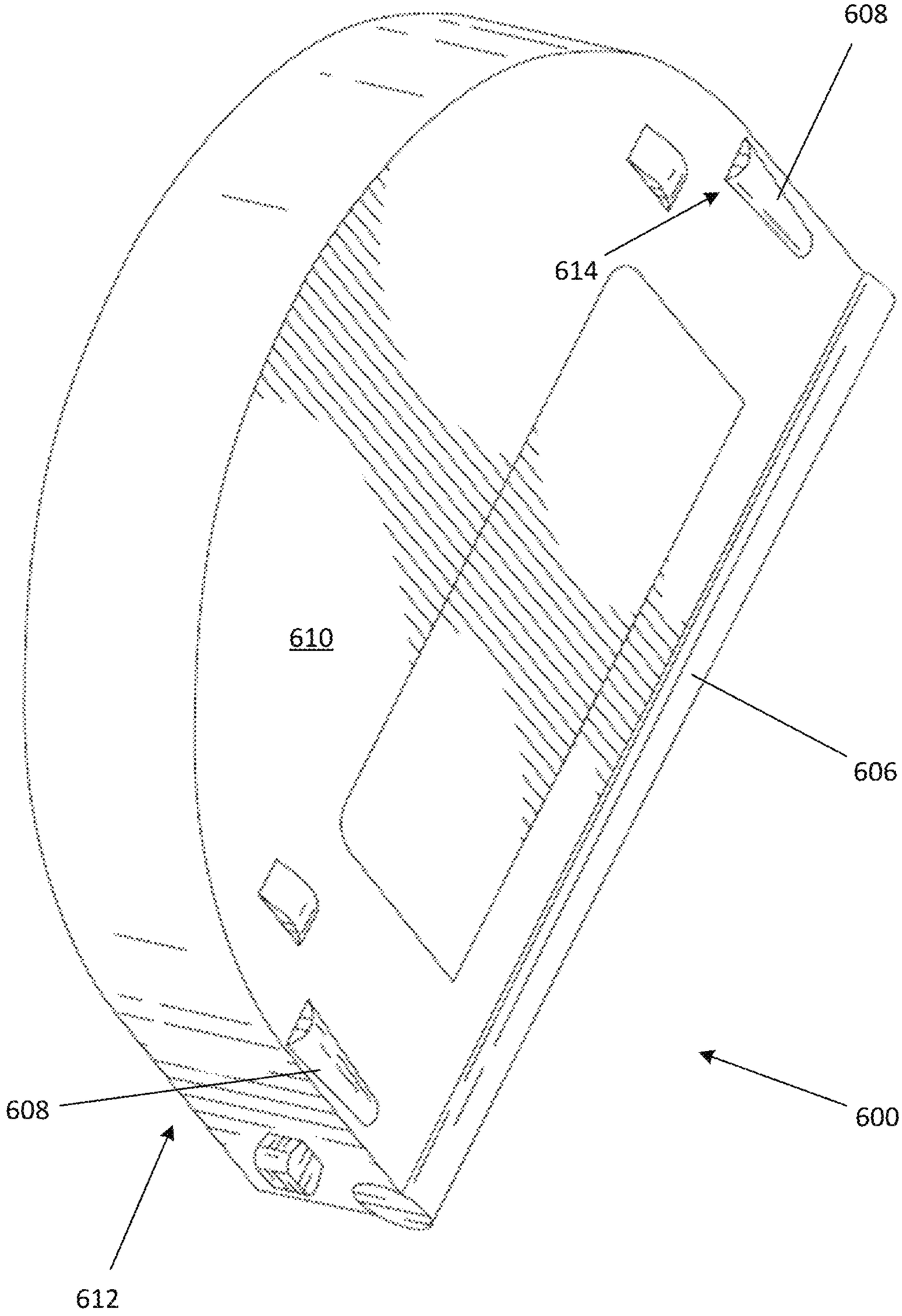


FIG. 8

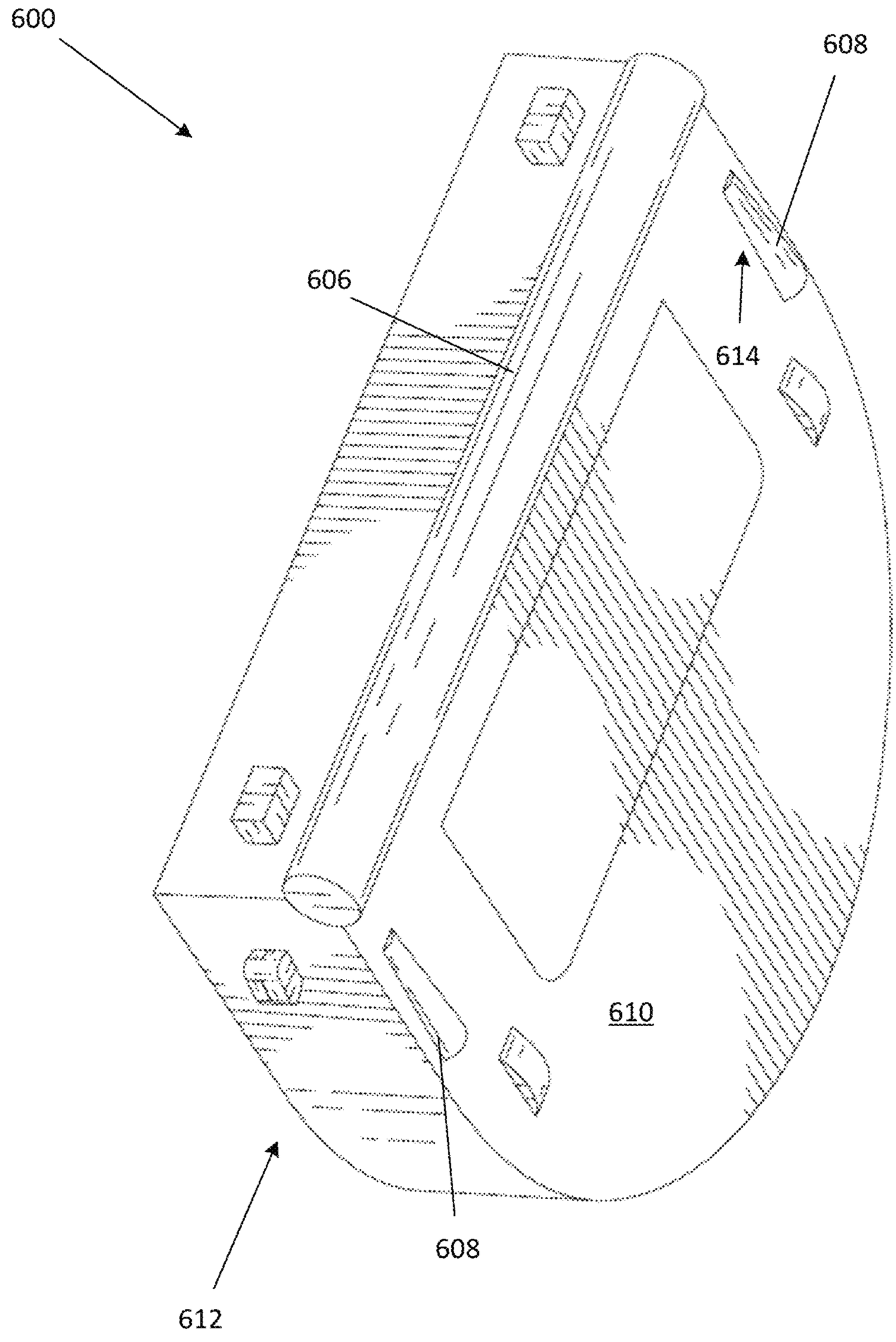


FIG. 9

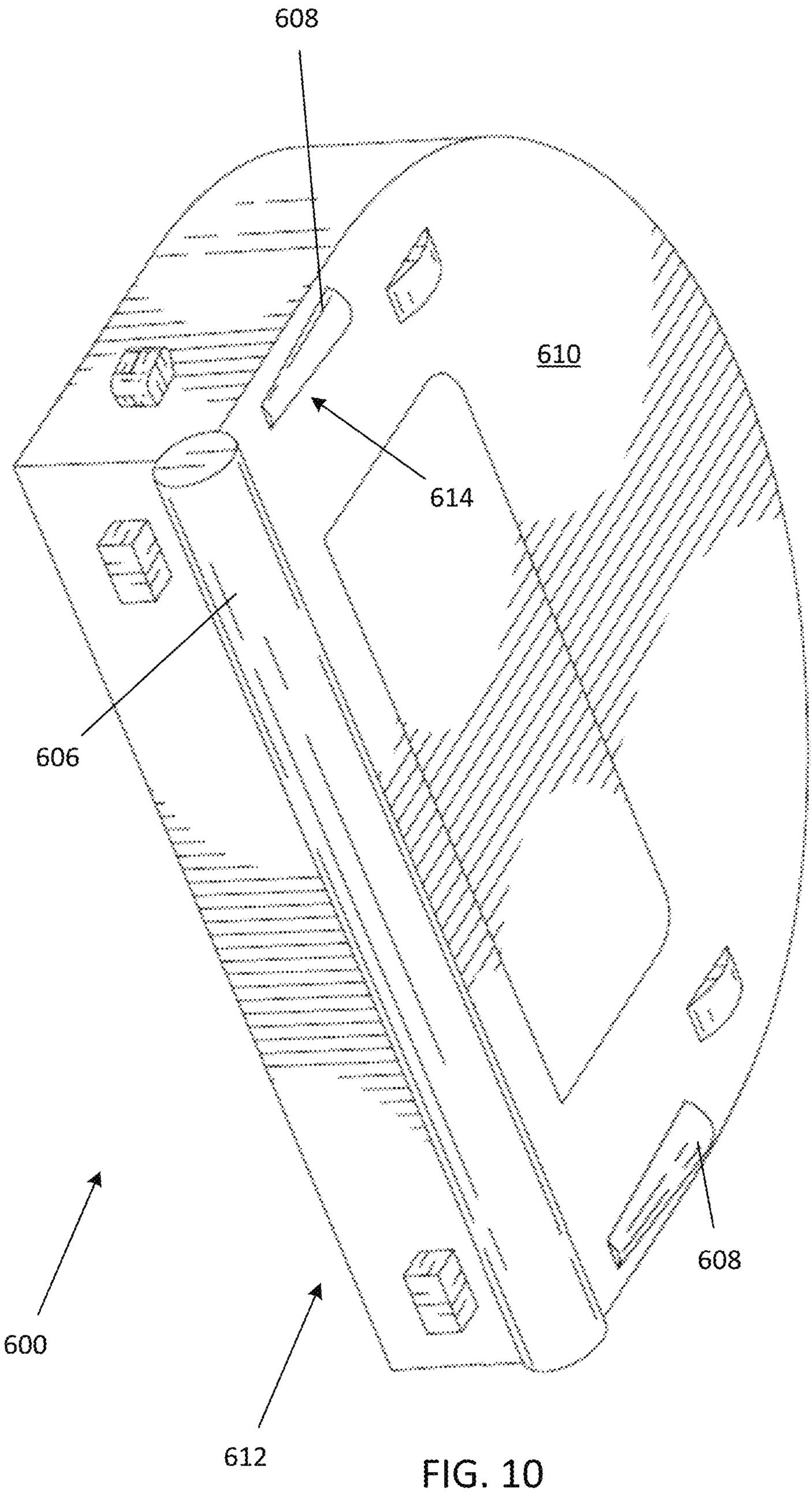


FIG. 10

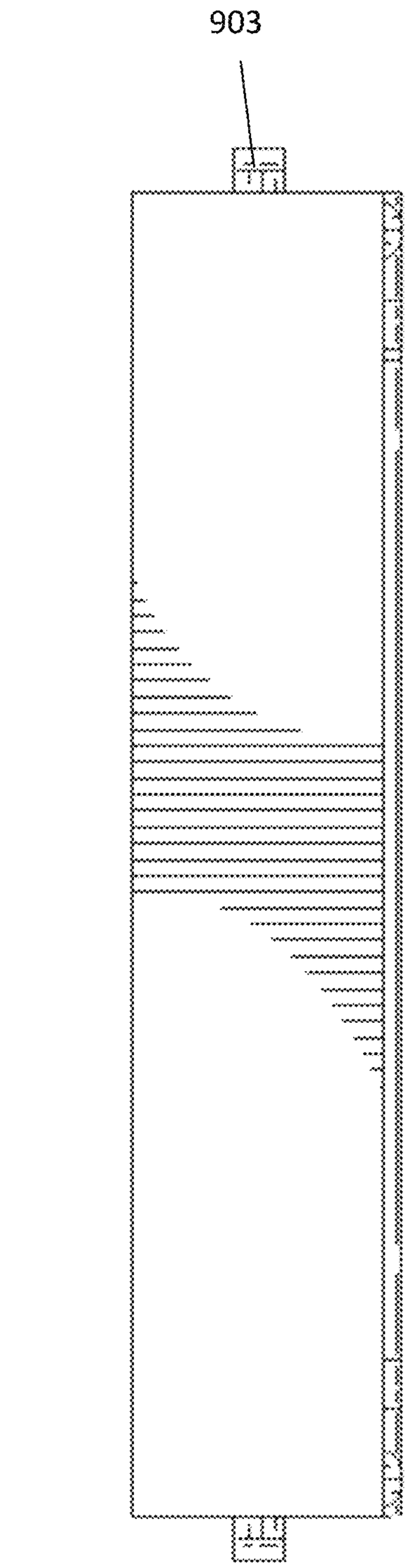


FIG. 11

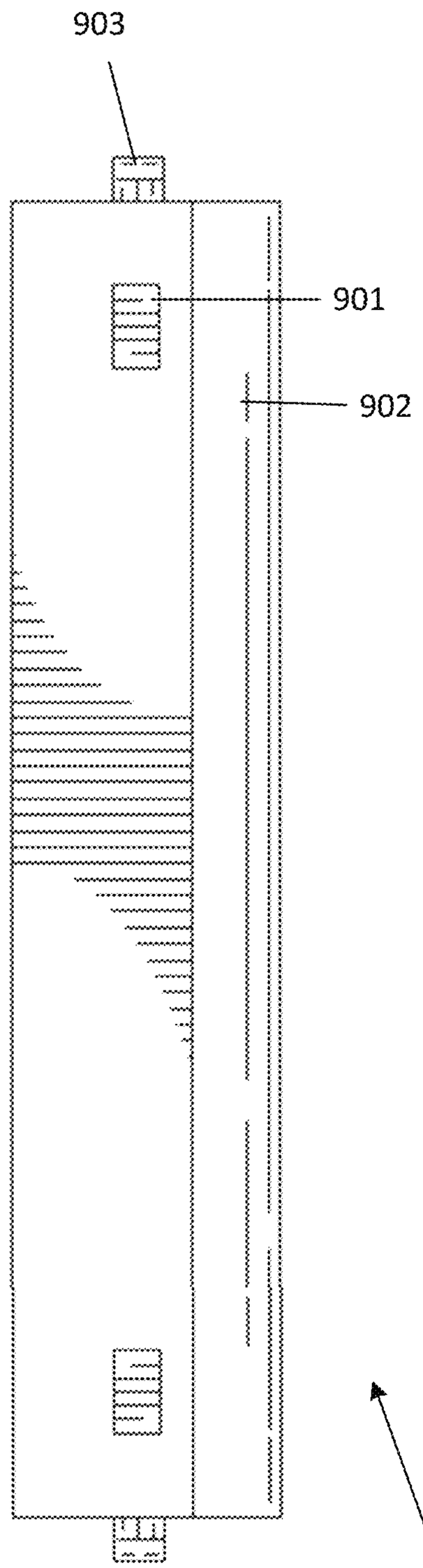


FIG. 12

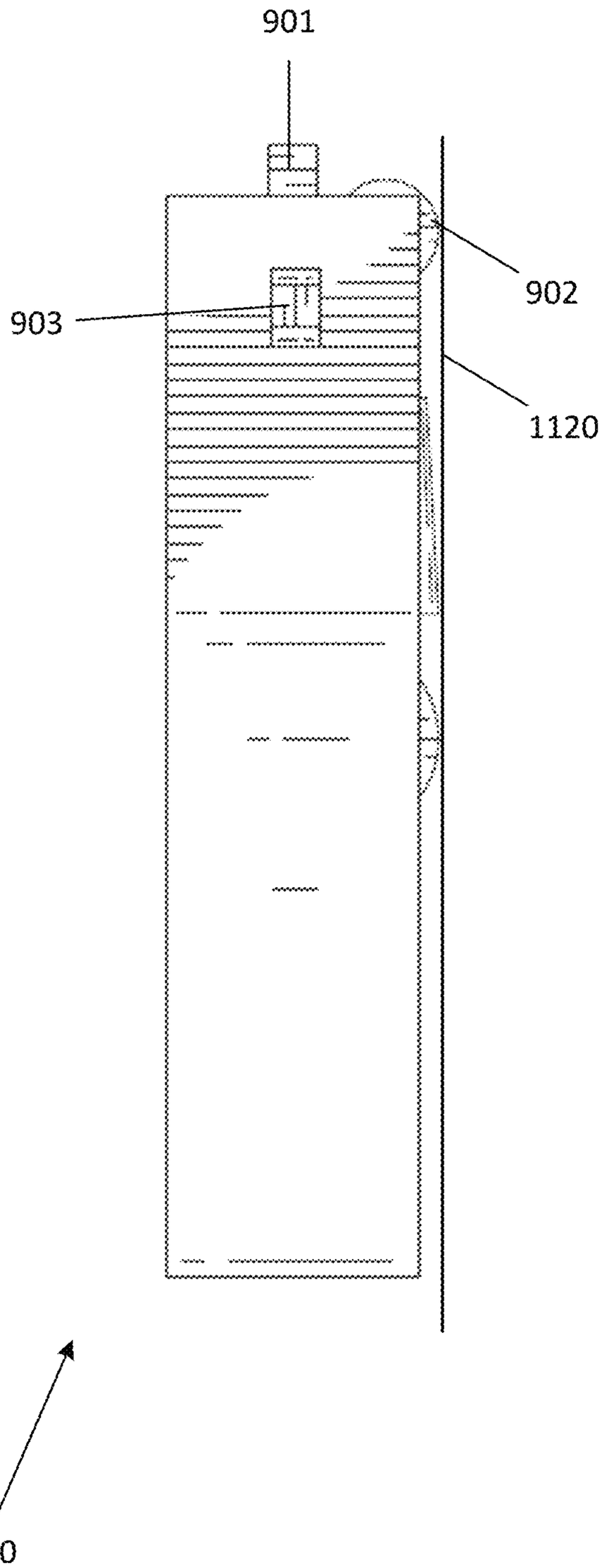


FIG. 13

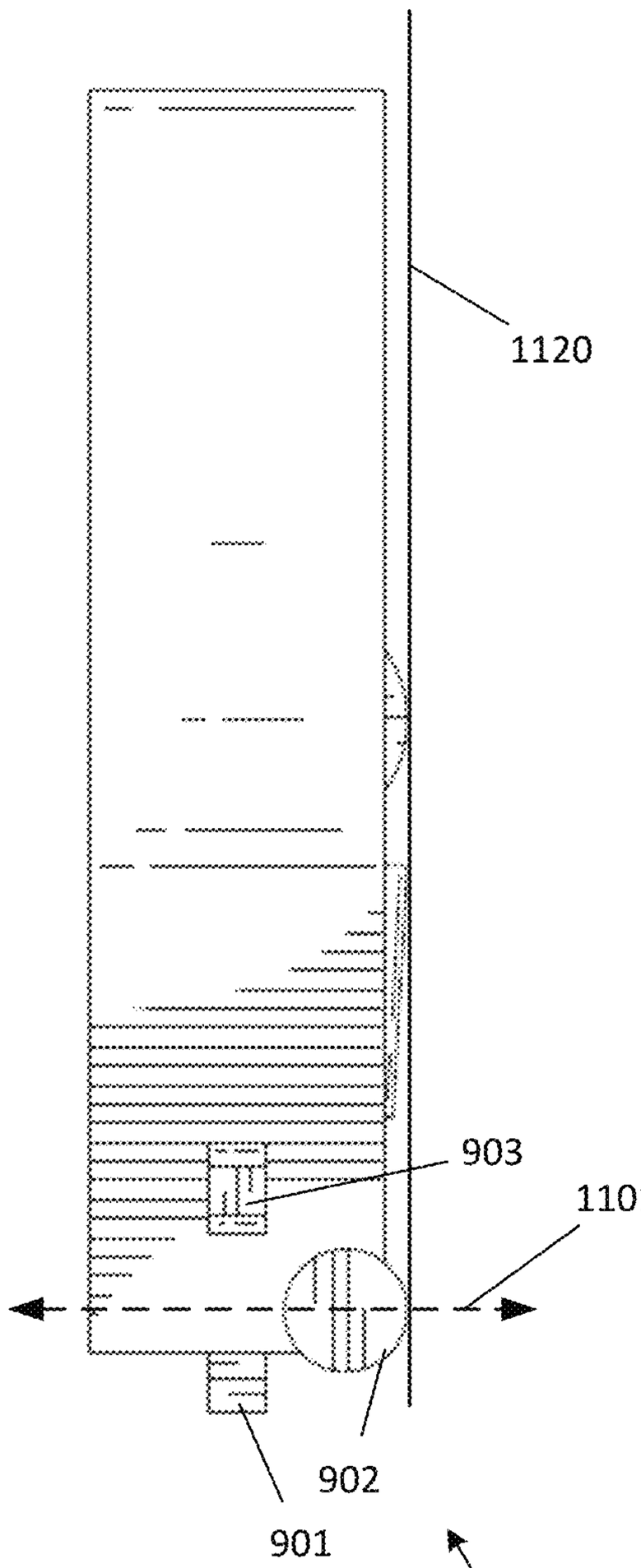


FIG. 14

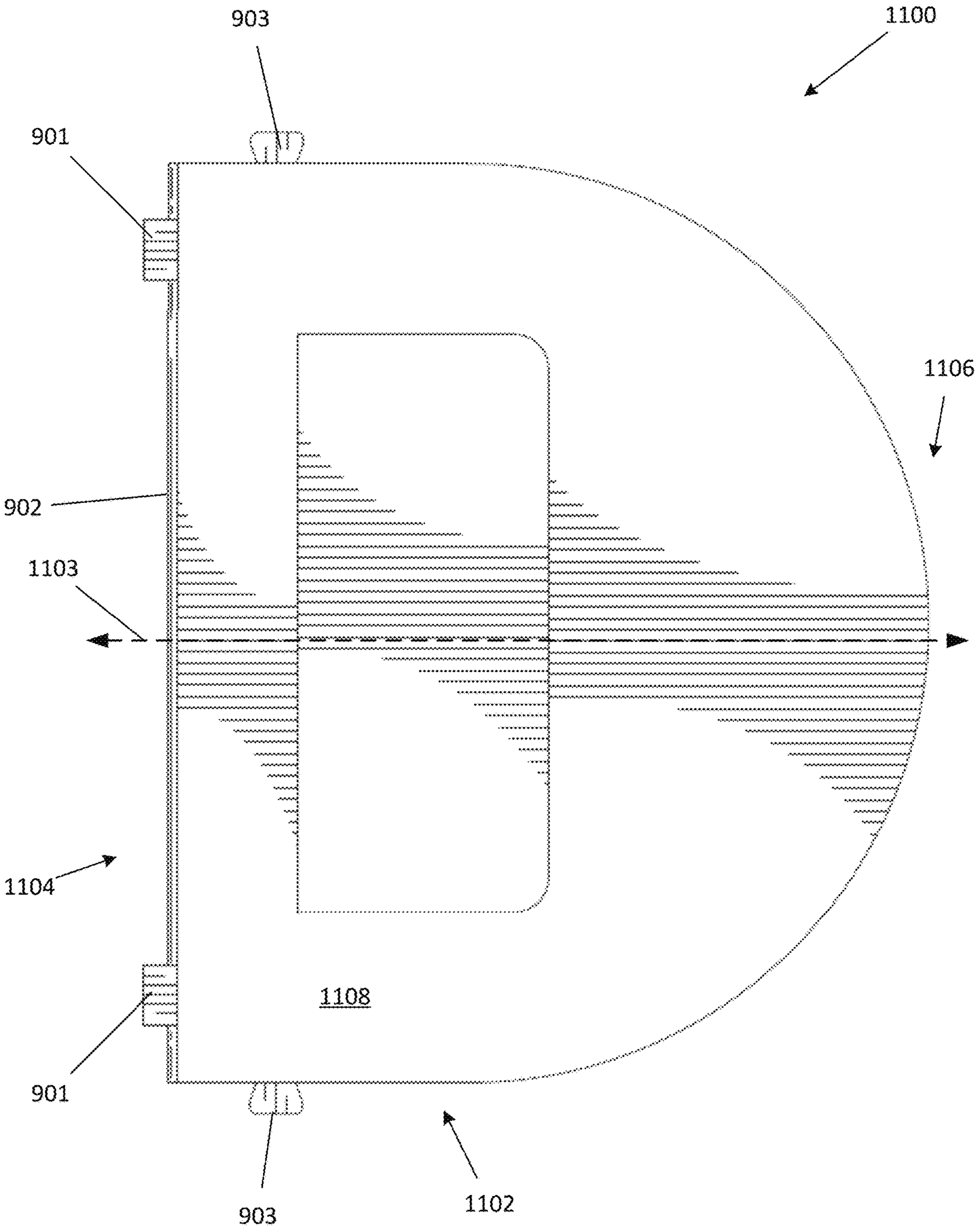


FIG. 15

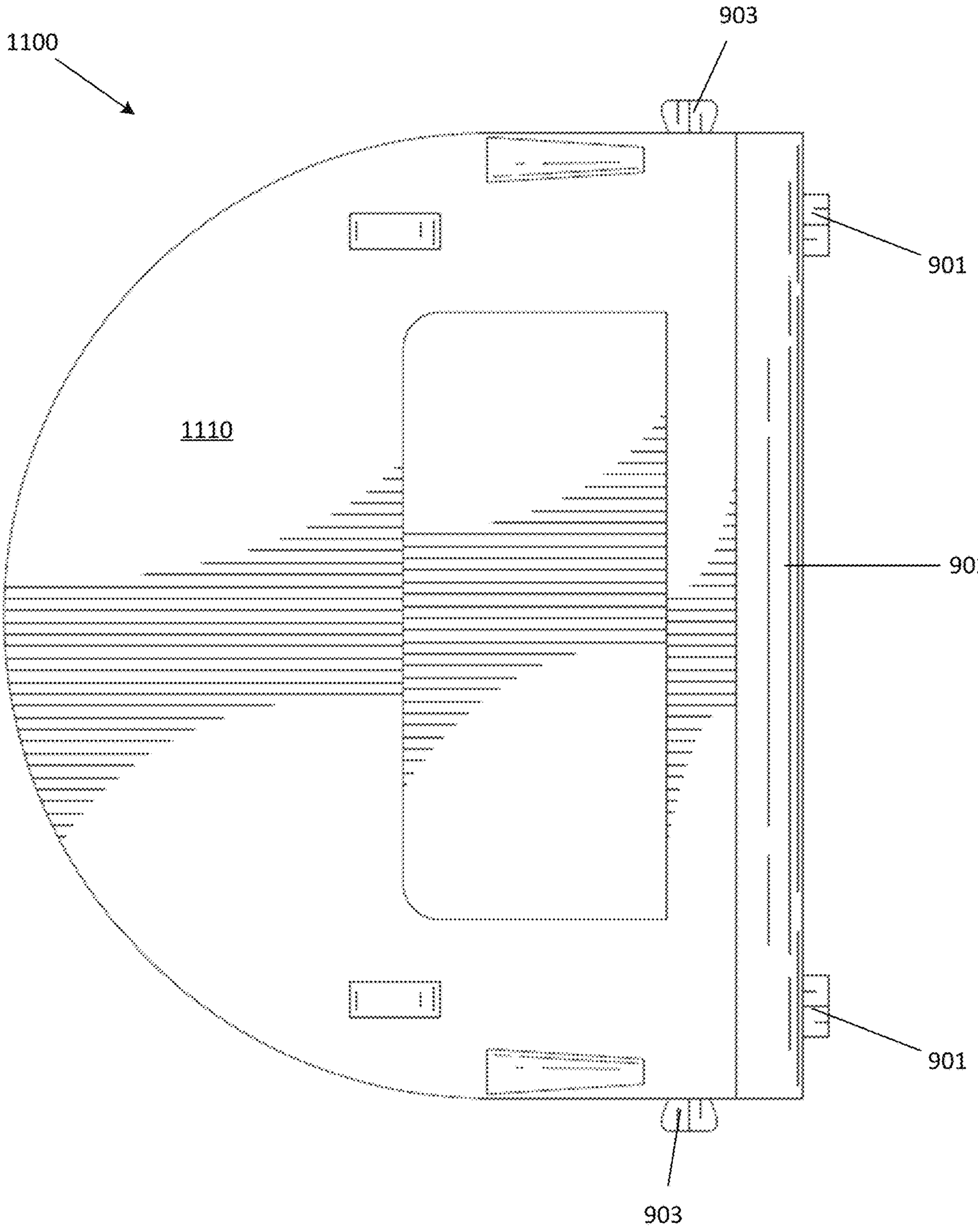


FIG. 16

ROBOTIC CLEANER

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of U.S. Provisional Application Ser. No. 62/945,684 filed on Dec. 9, 2019, entitled Robotic Cleaner with Edge Cleaning, which is fully incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to autonomous devices and, more particularly to, robotic cleaners.

BACKGROUND INFORMATION

Robotic cleaners have become an increasingly popular appliance for automated cleaning applications. In particular, robotic vacuum cleaners are used to vacuum surfaces while moving around surfaces with little or no user interaction. Robotic vacuum cleaners include a suction system. Robotic vacuum cleaners may also include one or more cleaning implements such as one or more agitators (e.g., rotating brush rolls) and/or one or more side brushes.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages will be better understood by reading the following detailed description, taken together with the drawings wherein:

FIG. **1** is a perspective view of a robotic cleaner, consistent with embodiments of the present disclosure.

FIG. **2** is a bottom view of an example of the robotic cleaner shown in FIG. **1**, consistent with embodiments of the present disclosure.

FIG. **3** is a perspective view of another example of the robotic cleaner of FIG. **1**, consistent with embodiments of the present disclosure.

FIG. **4**A is another perspective view of the robotic cleaner of the robotic cleaner of FIG. **3** having projections, consistent with embodiments of the present disclosure.

FIG. **4**B is a magnified view of a portion of the robotic cleaner of FIG. **4**A, illustrating the projections in greater detail, consistent with embodiments of the present disclosure.

FIG. **4**C is a magnified cross-sectional view illustrating an example of one of the projections of FIG. **4**B in greater detail, consistent with embodiments of the present disclosure.

FIG. **5** is a top perspective view of the robotic cleaner of FIG. **4**A, consistent with embodiments of the present disclosure.

FIG. **6** is a cross-sectional view of a robotic cleaner, consistent with embodiments of the present disclosure.

FIG. **7** is a bottom perspective view of the robotic cleaner of FIG. **6**, consistent with embodiments of the present disclosure.

FIG. **8** is another bottom perspective view of the robotic cleaner of FIG. **6**, consistent with embodiments of the present disclosure.

FIG. **9** is a front perspective view of the robotic cleaner of FIG. **6**, consistent with embodiments of the present disclosure.

FIG. **10** is another front perspective view of the robotic cleaner of FIG. **6**, consistent with embodiments of the present disclosure.

FIG. **11** is a rear view of a robotic cleaner, consistent with embodiments of the present disclosure.

FIG. **12** is a front view of the robotic cleaner of FIG. **11**, consistent with embodiments of the present disclosure.

FIG. **13** is a right view of the robotic cleaner of FIG. **11**, consistent with embodiments of the present disclosure.

FIG. **14** is a left view of the robotic cleaner of FIG. **11**, consistent with embodiments of the present disclosure.

FIG. **15** is a top view of the robotic cleaner of FIG. **11**, consistent with embodiments of the present disclosure.

FIG. **16** is a bottom view of the robotic cleaner of FIG. **11**, consistent with embodiments of the present disclosure.

DETAILED DESCRIPTION

The present disclosure is generally directed to a robotic cleaner. The robotic cleaner includes a housing and an agitator (e.g., a brush roll). The agitator may be configured to rotate about an agitator rotation axis that extends substantially parallel to a front side of the housing and to a surface to be cleaned (e.g., a floor). In some instances, one or more projections may extend from the housing. The one or more projections may include one or more cliff sensors that are configured to detect a non-traversable drop-off (or cliff) in the surface to be cleaned.

Additionally, or alternatively, in some instances, the robotic cleaner may include one or more spiral brushes. The one or more spiral brushes rotate about a spiral brush rotation axis that extends substantially parallel to the surface to be cleaned and transverse to (e.g., perpendicular to) the agitator rotation axis. Additionally, or alternatively, in some instances, the agitator may be configured to move along one or more of a drop axis and/or a forward bump axis. Movement along the drop axis is indicative of a presence of a non-traversable drop-off in the surface to be cleaned (or cliff) and movement along the forward bump axis is indicative of the presence of an obstacle.

As used herein, the terms "above" and "below" are used relative to an orientation of the cleaning apparatus on a surface to be cleaned and the terms "front" and "back" are used relative to a direction that the cleaning apparatus moves on a surface being cleaned during normal cleaning operations. As used herein, the term "leading" refers to a position in front of at least another component but does not necessarily mean in front of all other components.

FIG. **1** shows a perspective schematic view of an example of a robotic cleaner **101**, consistent with embodiments of the present disclosure. Although a particular embodiment of a robotic cleaner **101** is shown and described herein, the concepts of the present disclosure may apply to other types of robotic cleaners.

As shown, the robotic cleaner **101** includes a housing **100** having a front side **108**, a back side **109** that is opposite the front side **108**, a left side **112**, a right side **114** that is opposite the left side **112**, an upper side (or top surface) **110**, and an underside (or bottom surface) **111** that is opposite the top surface **110**. The left and right sides **112** and **114** extend between the front and back sides **108** and **109**. The back side **109** may have an arcuate shape (e.g., wherein the arc extends in a direction away from the front side **108**) and the front side **108** may have a substantially planar shape. As such, in some instances, the housing **100** may generally be described as having a "D-shape." While the robotic cleaner **101** is shown as having a D-shaped housing other configurations are possible. For example, the housing **100** may be round, oval, hexagonal, triangular, trapezoidal, and/or any other shape.

A user interface may extend along and/or define at least a portion of the top surface **110**. The user interface may include, for example, one or more indicators (e.g., one or more displays, one or more light emitting diodes, and/or any other indicator) configured to indicate a status of the robotic cleaner **101** (e.g., current operational mode, battery charge level, errors, and/or any other status), one or more inputs (e.g., buttons) configured to cause the robot to engage in one or more operations (e.g., autonomous cleaning, spot cleaning, docking, and/or any other operation), and/or any other feature of a user interface.

FIG. **2** shows a bottom view of a robotic cleaner **200**, which may be an example of the robotic cleaner **101** of FIG. **1**. As shown, the robotic cleaner **200** includes a first agitator **202** and a second agitator **204** (e.g., a brush roll). In some instances, the first agitator **202** may have a different construction from the second agitator **204** (e.g., the first agitator **202** may comprise a microfiber and/or velvet material and the second agitator **204** may comprise one or more bristles and/or flaps).

The first agitator **202** may have bristles, fabric, or any other cleaning element, or any combination thereof. In one example, a microfiber or velvet fabric may extend around the first agitator **202**. The first agitator **202** may also be removable to allow first agitator **202** to be cleaned more easily, allow the user to change the size of the first agitator **202**, change the type of bristles on the first agitator **202**, and/or remove the first agitator **202** entirely depending on the intended application.

The second agitator **204** may have bristles, fabric, or any other cleaning element, or any combination thereof. In one example, the second agitator **204** may include one or more strips of bristles in combination with one or more strips (or flaps) of a rubber or elastomer material. The second agitator **204** may also be removable to allow second agitator **204** to be cleaned more easily, allow the user to change the size of the second agitator **204**, change the type of bristles on the second agitator **204**, and/or remove the second agitator **204** entirely depending on the intended application.

In operation, the first and second agitators **202** and **204** are configured to rotate about a corresponding agitator rotation axis **201** and **205**. The rotation axes **201** and **205** may extend substantially (e.g., within 1°, 2°, 3°, 4°, or 5° of) parallel to each other and/or extend substantially parallel to a surface to be cleaned. As such, the rotation axes **201** and **205** may, in some instances, be generally described as horizontal rotation axes. The first and second agitators **202** and **204** may be co-rotating or counter rotating. As shown, in some instances, one or more of the rotation axes **201** and/or **205** may extend substantially parallel to a front side **250** of a housing **252** of the robotic cleaner **200**.

The first and second agitators **202** and **204** can be configured to rotate about the rotation axes **201** and **205** such that debris on a surface to be cleaned is urged towards a dirty air (or debris) inlet defined with an agitator chamber (or suction conduit) **248**. The agitator chamber **248** may define a cavity within which the first and second agitators **202** and **204** are at least partially disposed. The cavity may have one or more open ends through which at least a portion of one or more of the agitators **202** and **204** may extend. The cavity may further be coupled to the dirty air inlet. At least one open end of the cavity may be defined in a bottom surface **251** of the housing **252** of the robotic cleaner **200**.

The dirty air inlet is fluidly coupled to a debris collector (or dust cup) and to a suction source (e.g., a suction motor) such that at least a portion of debris urged towards the dirty air inlet becomes entrained within air flowing into the dirty air inlet. At least a portion of the entrained debris may be deposited within the debris collector. The debris collector may be removably coupled to the housing **252** of the robotic cleaner **200** such that debris may be emptied therefrom. Rotation of the first and second agitators may be caused using one or more motors **249** (e.g., AC or DC motors). The one or more motors may be coupled to the first and second agitators **202** and **204** using one or more drive belts, one or more gears, and/or any other drive mechanism.

As shown, the first agitator **202** extends from the front side **250** of the housing **252** of the robotic cleaner **200**. As such, the first agitator **202** may define a forward most portion of the robotic cleaner **200**. In this example, the first rotation axis **201** may be positioned forward of the second rotation axis **205** such that, for example, the first rotation axis **201** extends between the front side **250** and the second rotation axis **205**. While the first agitator **202** is shown as being forward of the second agitator **204**, other configurations are possible. For example, the first agitator **202** may be positioned rearward of the second agitator **204**. In this example, the second agitator may define a forward most portion of the robotic cleaner **200**. Further, while the robotic cleaner **200** is shown as having a first and second agitator **202** and **204**, other configurations are possible. For example, the robotic cleaner **200** may include only one of the first or second agitators **202** and **204** and/or include additional agitators.

The robotic cleaner **200** also includes wheels **203** configured to be driven by one or more drive motors. The wheels **203** support the housing **252** at a position spaced apart from a surface to be cleaned and are configured to urge the robotic cleaner **200** across the surface to be cleaned in response to actuation of the one or more drive motors. The wheels **203** may be independently driven such that a direction of motion of the robotic cleaner **200** can be controlled through differential rotation of the wheels **203**. The wheels **203** may be mounted on respective suspension systems that bias the wheels in a direction away from the housing **252** (e.g., towards an extended position). For example, the suspension system may include a suspension arm pivotally coupled to the housing **252** such that the suspension arm is capable of transitioning between a retracted position and an extended position. The suspension system may further include a biasing mechanism (e.g., a spring) that urges the suspension arm towards the extended position. In some instances, one or more of a respective drive motor and/or a respective gearbox for transferring rotational movement from the drive motor to a respective wheel **203** may be coupled to the suspension arm. As such, the motor and/or gearbox may move with the suspension arm.

During operation, a weight of the robotic cleaner **200** causes the suspension systems of the respective wheels **203** to be in an intermediate position, the intermediate position being between the extended and retracted positions. A location of the intermediate position, relative to the extended and retracted positions, may vary based, at least in part, on the surface to be cleaned. The robotic cleaner **200** may also include wheel drop sensors (e.g., switches engaged by the suspension arm) to detect when the wheels are in the extended position.

The robotic cleaner **200** may include a controller configured to monitor sensor data (e.g., from one or more obstacle sensors, one or more floor type sensors, and/or any other sensors) and to control operation of the robotic cleaner **200** (e.g., based on the sensor data). For example, the controller may be communicatively coupled to one or more driving mechanisms (e.g., drive wheel motors, agitator motors, side

brush motors, and/or any other driving mechanism) and one or more sensors. The controller can operate the drive motors, which drive the wheels, according to known techniques in the field of robotic cleaners. The controller may also cause the robotic cleaner **200** to perform various operations such as autonomous cleaning (including randomly moving and turning, wall following, and obstacle following), spot cleaning, and docking. The controller may also cause the robotic cleaner **200** to avoid obstacles and cliffs and to escape from various situations where the robotic cleaner **200** may become stuck. The controller may include any combination of hardware (e.g., one or more microprocessors) and software known for use in mobile robots.

FIG. **3** shows a perspective view of a robotic cleaner **300**, which may be an example of the robotic cleaner **101** of FIG. **1**. As shown, the robotic cleaner **300** includes a housing **301** having a front side **310**, a back side **312** that is opposite the front side **310**, a left side **314**, a right side **316** that is opposite the left side **314**, an upper side (or top surface) **318**, and an underside (or bottom surface) **320** that is opposite the top surface **318**. One or more projections **302** may extend from the housing **301**. In some instances, the one or more projections **302** may define a distal most portion of the robotic cleaner **300**. In other instances, the one or more projections **302** may not define a distal most portion of the robotic cleaner **300**.

The one or more projections **302** may include and/or be configured to actuate one or more sensors **303**. For example, the one or more sensors **303** may include one or more cliff sensors configured to detect a non-traversable drop-off in the surface to be cleaned (or cliff). When the projections **302** are not the distal most portion of the robotic cleaner **300**, the projections **302** may include one or more reflectors configured to enable corresponding cliff sensors to transmit and receive cliff detection signals to and from the surface to be cleaned. For example, for an infrared (IR) cliff sensor, the one or more projections **302** may include a mirrored surface configured to direct IR emissions towards the surface to be cleaned. Additionally, or alternatively, the one or more projections **302** may be configured to transition between an extended and retracted position such that the one or more projections **302** are configured to transition towards a retracted position in response to contacting an obstacle. When in the retracted position, the one or more projections **302** may be configured to actuate at least one of the one or more sensors **303**, wherein actuation of the sensor **303** causes the sensor **303** to generate a signal indicating an obstacle has been encountered. In other words, when transitioning into the retracted position, the one or more projections **302** may cause an obstacle detection signal to be generated. In some instances, the robotic cleaner **300** may include a plurality of projections **302** that are spaced around the housing **301**.

The one or more projections **302** may extend from the housing **301** at a position between the top surface **318** and the bottom surface **320**. For example, the one or more projections **302** may be centrally disposed between the top and bottom surface **318** and **320**. By way of further example, the projections **302** may be disposed at a position closer to the top surface **318** than the bottom surface **320**. By way of still further example, the projections **302** may be disposed at a position closer to the bottom surface **320** than the top surface **318**.

FIGS. **4**A and **5** show a schematic example of the robotic cleaner **300** having a plurality of projections **302**. As shown, the plurality of projections **302** include at least one forward projection **401** and at least one a side projection **403**. The projections **401** and **403** include cliff sensors configured to detect a non-traversable drop-off (e.g., stairs) in the surface to be cleaned. The forward projection **401** extends from the front side **310** of the housing **301** and each side projection **403** extends from a respective one of the left side **314** or the right side **316**.

The projections **401** and **403** are displaceable such that the projections **401** transition between extended and retracted positions (e.g., in response to engaging an obstacle). The projections **401** and **403** can be biased (e.g., using one or more springs) towards the extended position. As such, after disengaging an obstacle (e.g., a wall), the projections **401** and **403** transition towards the extended position. When transitioning between the extended and retracted positions, the projections **401** and **403** may move within a plane that extends substantially parallel to the top surface **318** of the housing **301** (e.g., a horizontal plane).

When in the extended position, the projections **401** and **403** may represent the distal most portions of the robotic cleaner **300**. When in the retracted position, the projections **401** and **403** may not be the distal most portion of the robotic cleaner **300**. For example, an agitator **404** of the robotic cleaner **300** may define the forward most portion of the robotic cleaner **300** (or the distal most portion in the forward direction) when the forward projection **401** is in the retracted position and, when the forward projection **401** is in the extended position, the forward projection **401** may extend beyond the agitator **404** such that the forward projection **401** defines the forward most portion of the robotic cleaner **300**. Such a configuration may allow the agitator **404** to engage (e.g., contact) an obstacle (e.g., a wall) extending from a surface to be cleaned. By way of further example, the agitator **404** of the robotic cleaner **300** may define the left and/or right most portions of the robotic cleaner **300** (or the distal most portion in the left and/or right direction) when the side projection **403** is in the retracted position and, when the side projection **403** is in the extended position, the side projection **403** may extend beyond the agitator **404** such that the side projection **403** defines the left and/or right most portions of the robotic cleaner **300**.

When the projections **401** and/or **403** transition into the retracted position, the projections **401** and/or **403** may actuate a respective sensor **303** (e.g., a switch such as a mechanical or optical switch) that generates a signal that is indicative of an obstacle being contacted. When the signal is received by a controller of the robotic cleaner **300**, the controller may cause the robotic cleaner **300** to engage in one or more behaviors (e.g., obstacle avoidance, obstacle cleaning, and/or any other behavior).

FIG. **4**B shows a magnified perspective view of a portion of the robotic cleaner **300**. As shown, the forward projection **401** may move linearly when transitioning between the extended and retracted positions and the side projection **403** may move pivotally when transitioning between the extended and retracted positions. However, other configurations are possible. For example, when transitioning between the extended and retracted positions, both projections **401** and **403** may move linearly, both projections **401** and **403** may move pivotally, or the forward projection **401** may move pivotally and the side projection **403** may move linearly.

FIG. **4**C shows a schematic example of the side projection **403**, wherein the side projection **403** is configured to pivot about a pivot point **410**. The pivot point **410** may be disposed within the housing **301** of the robotic cleaner **300** (e.g., the side projection **403** may be pivotally coupled to a chassis **411** of the robotic cleaner **300**) such that, when

transitioning into the retracted position, at least a portion of the side projection **403** moves into the housing **301**. A biasing mechanism (e.g., a spring) may urge the side projection **403** to pivot towards the extended position. When the side projection **403** encounters an obstacle, the side projection **403** is caused to pivot towards the retracted position. As shown, the side projection **403** may pivot in a substantially horizontal plane between the retracted and extended positions.

As also shown in FIG. **4**C, the side projection **403** may have a triangular shape, wherein the triangular shape may have rounded points. Such a configuration may encourage the transition of the side projection **403** between the extended position and the retracted position in response to engaging an obstacle. Other shapes are also within the scope of the present disclosure including, for example, oval, octagonal, or any other shape.

FIG. **6** shows a schematic cross-sectional view of a robotic cleaner **600**, which may be an example of the robotic cleaner **300** of FIG. **3**. As shown, the robotic cleaner **600** may include a plurality of forward projections **602** and a plurality of side projections **604**, which may be examples of the forward and side projections **401** and **403**, respectively. One or more of the forward and/or side projections **602** and **604** are configured to transition between extended and retracted positions in response to engaging an obstacle. At least one of the forward and/or side projections **602** and **604** extend beyond an agitator **606** when in the extended position. The agitator **606** may extend beyond at least one of the forward and/or side projections **602** and **604** when an obstacle causes a respective projection **602** or **604** to transition to the retracted position.

FIGS. **7-10** show various perspective bottom views of the robotic cleaner **600** of FIG. **6**. As shown, the robotic cleaner **600** includes one or more spiral brushes **608** configured to rotate about a spiral brush rotation axis **609**. The spiral brush rotation axis **609** is configured to extend substantially parallel to a bottom surface **610** of a housing **612** of the robotic cleaner **600** and/or to a surface to be cleaned. As shown, the one or more spiral brushes **608** extend along the spiral brush rotation axis **609** in a direction transverse (e.g., perpendicular) to a longitudinal length of the agitator **606**. In other words, the spiral brush rotation axis **609** may extend transverse (e.g., perpendicular) to an agitator rotation axis **611** about which the agitator **606** rotates. In some instances, the spiral brush rotation axis **609** may intersect the agitator **606**. The agitator rotation axis **611** may extend substantially parallel to the bottom surface **610** and/or to a surface to be cleaned. As such, in some instances, the agitator rotation axis **611** and the spiral brush rotation axis **609** may generally be described as being horizontal rotation axes.

The transverse positioning (relative to the agitator **606**) of one or more spiral brushes **608** may allow for cleaning transverse to the agitator **606**. For example, such a configuration may allow the robotic cleaner **600** to clean alongside an obstacle or drop-off using the one or more spiral brushes **608**. Such a configuration may generally be described as creating a longer agitating surface along the edge of the obstacle or drop-off.

The one or more spiral brushes **608** may have a frustoconical shape about which one or more cleaning elements may extend. However, the one or more spiral brushes **608** may have any shape including cylindrical, octagonal, and/or any other shape. The cleaning elements may include any one or more of bristles, flaps, fabric (e.g., a velvet or microfiber), and/or any other cleaning element. For example, the one or more spiral brushes **608** may include at least one strip of bristles and at least one elastomeric flap extending along a body of the one or more spiral brushes **608** (e.g., in a helical pattern). Rotation of the one or more spiral brushes **608** causes the cleaning elements to engage the surface to be cleaned such that debris on the surface is urged towards a suction conduit. Rotation of the spiral brush **608** can be caused by one or more spiral brush motors.

The one or more spiral brushes **608** may be received within a spiral brush cavity **614**, wherein at least a portion of the one or more spiral brushes **608** extend from an open end of the spiral brush cavity **614** in a direction of a surface to be cleaned. The spiral brush cavity **614** may include one or more couplings for rotatably coupling the one or more spiral brushes **608** to the housing **612**. At least one of the one or more couplings may couple the one or more spiral brushes **608** to a respective spiral brush motor. In some instances, the one or more spiral brushes **608** may be removably coupled to the housing **612**. Such a configuration may allow the one or more spiral brushes **608** to be more easily cleaned and/or replaced. Replacement of the one or more spiral brushes **608** may allow a user to select a spiral brush based on a desired cleaning behavior (e.g., a spiral brush with different cleaning elements and/or different size/shape). In some instances, the one or more spiral brushes **608** may be removed entirely and the robotic cleaner **600** may be configured to operate without the one or more spiral brushes.

FIGS. **11-16** show schematic examples of a robotic cleaner **1100**, which may be an example of the robotic cleaner **101** of FIG. **1**. As shown, the robotic cleaner **1100** includes a housing **1102** and an agitator **902** configured to be rotated relative to the housing **1102**. The agitator **902** can be configured to detect engagement with an obstacle and/or an existence of a non-traversable drop-off (or cliff). For example, the agitator **902** can be configured to move along one or more of a drop axis **1101** and/or a forward bump axis **1103**, wherein movement along the drop axis **1101** and/or the forward bump axis **1103** may be configured to actuate a sensor (e.g., an optical or mechanical switch), generating a detection signal, after a predetermined amount of movement. As such, movement of the agitator **902** along the forward bump axis **1103** may be indicative of a presence of an obstacle extending from a surface to be cleaned **1120**, wherein the obstacle impedes forward movement of the robotic cleaner **1100**, and movement of the agitator **902** along the drop axis **1101** may be indicative of a presence of a non-traversable drop-off (or cliff). Therefore, in some instances, the agitator **902** may generally be described as providing obstacle and/or drop-off sensing. When the agitator **902** moves along both the drop axis **1101** and the forward bump axis **1103**, the agitator **902** may be generally be described as being configured to float.

The forward bump axis **1103** extends substantially parallel to a direction of forward movement of the robotic cleaner **1100** and the drop axis **1101** extends substantially perpendicular to a surface to be cleaned **1120**. In other words, the forward bump axis **1103** extends transverse (e.g., perpendicular) to a front side **1104** and a back side **1106** of the housing **1102** of the robotic cleaner **1100** and the drop axis **1101** extends transverse (e.g., perpendicular) to an upper side **1108** and an underside **1110** of the housing **1102**. As such, when the agitator **902** is capable of moving along both the forward bump axis **1103** and the drop axis **1101**, the forward bump axis **1103** may generally be described as extending transverse (e.g., perpendicular) to the drop axis **1101**. In some instances, the forward bump axis **1103** may

generally be described as being a horizontal axis and the drop axis **1101** may generally be described as being a vertical axis.

In some instances, movement of the agitator **902** along one or more of the drop axis **1101** and/or the forward bump axis **1103** may be caused by movement of a sole plate. For example, the agitator **902** may be rotatably coupled to the sole plate such that a movement of the sole plate is transferred to the agitator **902**. In this example, when the robotic cleaner **1100** encounters a non-traversable drop-off, the sole plate may move along the drop axis **1101** along with the agitator **902**. Alternatively, the sole plate may move independently from the agitator **902** (e.g., the agitator may be fixed relative to the drop axis **1101** and the forward bump axis **1103**) such that movement of the sole plate is indicative of the presence of an obstacle and/or a non-traversable drop-off. Movement of the sole plate may actuate a sensor (e.g., switch) configured to generate a signal indicative of a non-traversable drop-off and/or obstacle being encountered.

When the agitator **902** is configured to provide obstacle and/or non-traversable drop-off sensing, additional obstacle and/or non-traversable drop-off sensors may be omitted. For example, one or more forward and/or side projections **901** and/or **903** having cliff sensors may be omitted. Alternatively, for example, the robotic cleaner may include one or more forward and/or side projections **901** and/or **903** having cliff sensors to increase a confidence level in detecting a non-traversable drop-off. Such configurations may allow the agitator **902** to clean the edge of the drop-off before engaging in a cliff avoidance behavior (e.g., turning and/or reversing). By way of further example, when the agitator **902** provides forward obstacle detection, a bumper may be omitted and the agitator **902** may define the forward most portion of the robotic cleaner **1100**. Such a configuration may allow the robotic cleaner **1100** to clean at least a portion of a vertically extending surface of the obstacle (e.g., a leg of a piece of furniture such as a chair or a wall) using the agitator **902** before engaging in an obstacle avoidance behavior (e.g., turning and/or reversing).

An example of a robotic cleaner, consistent with the present disclosure, may include a housing, an agitator, and one or more projections. The housing may have a front side, a back side opposite the front side, a left side, and a right side opposite the left side. The right and left sides extend between the front and back sides. The agitator may be configured to rotate about an agitator rotation axis, the agitator rotation axis extending substantially parallel to the front side. The one or more projections may extend from the housing. The one or more projections may include one or more cliff sensors.

In some instances, the one or more projections may include at least one forward projection and at least one side projection, the at least one forward projection extending from the front side of the housing and the at least one side projection extending from a respective one of the left side or the right side of the housing. In some instances, the agitator may extend from the front side of the housing. In some instances, the forward projection may extend beyond the agitator. In some instances, the one or more projections may be configured to transition between an extended position and a retracted position in response to engaging an obstacle. In some instances, when at least one of the one or more projections transition into the retracted position, an obstacle detection signal may be caused to be generated. In some instances, the agitator may be configured to move along at least one of a drop axis or a forward bump axis. In some instances, the agitator may be configured to move along the drop axis and movement along the drop axis may be indicative of a presence of a cliff. In some instances, the agitator may extend from the front side of the housing and may be configured to move along the forward bump axis, movement along the forward bump axis may be indicative of a presence of an obstacle. In some instances, the robotic cleaner may further include a spiral brush configured to rotate about a spiral brush rotation axis, the spiral brush rotation axis extending substantially parallel to a surface to be cleaned and transverse to the agitator rotation axis.

Another example of a robotic cleaner, consistent with the present disclosure, may include a housing having a front side and a back side opposite the front side and an agitator extending from the front side of the housing. The agitator may be configured to rotate about an agitator rotation axis. The agitator rotation axis may extend substantially parallel to the front side. The agitator may be further configured to move along a drop axis and a forward bump axis. Movement along the drop axis may be indicative of a presence of a cliff and movement along the forward bump axis may be indicative of a presence of an obstacle.

In some instances, the robotic cleaner may further include one or more projections extending from the housing and the one or more projections may include one or more cliff sensors. In some instances, the one or more projections may be configured to transition between an extended position and a retracted position in response to engaging an obstacle. In some instances, when at least one of the one or more projections transition into the retracted position, an obstacle detection signal may be caused to be generated. In some instances, the robotic cleaner may further include a spiral brush configured to rotate about a spiral brush rotation axis, the spiral brush rotation axis extending substantially parallel to a surface to be cleaned and transverse to the agitator rotation axis.

Another example of a robotic cleaner, consistent with the present disclosure, may include a housing, an agitator, and a spiral brush. The housing may have a front side and a back side opposite the front side. The agitator may be configured to rotate about an agitator rotation axis. The agitator rotation axis may extend substantially parallel to the front side and substantially parallel to a surface to be cleaned. The spiral brush may be configured to rotate about a spiral brush rotation axis. The spiral brush rotation axis may extend substantially parallel to the surface to be cleaned and transverse to the agitator rotation axis.

In some instances, the robotic cleaner may further include one or more projections extending from the housing and the one or more projections may include one or more cliff sensors. In some instances, the one or more projections may be configured to transition between an extended position and a retracted position in response to engaging an obstacle. In some instances, when at least one of the one or more projections transition into the retracted position, an obstacle detection signal may be caused to be generated. In some instances, the agitator may be further configured to move along a drop axis and a forward bump axis, movement along the drop axis may be indicative of a presence of a cliff and movement along the forward bump axis may be indicative of a presence of an obstacle.

While the principles of the invention have been described herein, it is to be understood by those skilled in the art that this description is made only by way of example and not as a limitation as to the scope of the invention. Other embodiments are contemplated within the scope of the present invention in addition to the exemplary embodiments shown and described herein. Modifications and substitutions by one

of ordinary skill in the art are considered to be within the scope of the present invention, which is not to be limited except by the following claims.

What is claimed is:

1. A robotic cleaner comprising:

a housing having a front side and a back side opposite the front side;

an agitator extending from the front side of the housing such that at least a portion of the agitator is exposed, the exposed portion of the agitator defines a forward most portion of the robotic cleaner and is configured to contact an obstacle, the agitator is further configured to rotate about an agitator rotation axis, the agitator rotation axis extends substantially parallel to the front side, the agitator is further configured to move along a drop axis and a forward bump axis, movement along the drop axis actuates a drop sensor, actuation of the drop sensor is indicative of a presence of a cliff and movement along the forward bump axis actuates a bump sensor, actuation of the bump sensor is indicative of a presence of the obstacle; and

a spiral brush configured to rotate about a spiral brush rotation axis, the spiral brush rotation axis is configured to extend substantially parallel to a surface to be cleaned and extends transverse to the agitator rotation axis.

2. The robotic cleaner of claim **1** further comprising one or more projections extending from the housing, the one or more projections including one or more cliff sensors.

3. The robotic cleaner of claim **2**, wherein the one or more projections are configured to transition between an extended position and a retracted position in response to engaging the obstacle.

4. The robotic cleaner of claim **3**, wherein, when at least one of the one or more projections transition into the retracted position, an obstacle detection signal is caused to be generated.

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